(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
23 October 2008 (23.10.2008)

PCT

(10) International Publication Number
WO 2008/128193 A1

(51) International Patent Classification:
A61K 31/00 (2006.01) *C07H 19/20* (2006.01)

(21) International Application Number:
PCT/US2008/060254

(22) International Filing Date: 14 April 2008 (14.04.2008)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/911,484 12 April 2007 (12.04.2007) US
60/956,689 18 August 2007 (18.08.2007) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

(54) Title: BIODEGRADABLE POLYANHYDRIDES WITH NATURAL BIOACTIVE MOLECULES

(57) Abstract: The invention provides polymers that include a biologically active molecule and methods for their use.

WO 2008/128193 A1

BIODEGRADABLE POLYANHYDRIDES WITH NATURAL BIOACTIVE MOLECULES

Priority of Invention

This application claims priority to United States Provisional Patent Application Number 60/956,689, filed 18 August 2007 and to United States Provisional Patent Application Number 60/911,484, filed 12 April 2007. The entire content of each of these provisional applications is hereby incorporated herein by reference.

Background

Biofilms and bacterial growth are currently a major problem in many industries including food, medicine and personal care. In essentially every field relating to hygiene, prevention of biofilms is a primary concern. Biofilm prevention is particularly important in the food processing industry as the attachment of bacteria and development of biofilms is a major cause of food spoilage and contamination. It is also critical to control biofilms on medical devices, wound care devices, personal care products and within surgical suites. Thus, products useful for inhibiting or preventing biofilm formation and thereby limiting bacterial growth are needed.

Methods to incorporate bioactive molecules with two or more functional groups into polymers have been described in US 7,122,615, US 6,613,807, US 2005/0089506 and US 2003/0035787. However, these methods are directed to bioactive molecules with two functional groups that allow the molecules to be incorporated into the backbone of the polymer.

Summary of Certain Embodiments of the Invention

Applicant has discovered a method to incorporate bioactive molecules into polymers, and in particular polyanhydrides, utilizing only one reactive functional group of the bioactive molecule. This discovery greatly increases the number and diversity of bioactive molecules that can be covalently linked to polyanhydrides.

In one embodiment the invention provides polymer comprising repeating units that form a biodegradable backbone wherein each repeating unit comprises at least two pendant residues of a biologically active molecule.

In one embodiment, the invention provides food products comprising a polymer or composition of the invention.

In one embodiment, the invention provides a confectionery (e.g. a chewing gum) comprising a polymer or composition of the invention.

In one embodiment, the invention provides a method for inhibiting biofilm formation on an area, comprising contacting the area with an effective amount of a polymer or composition of the invention.

In one embodiment, the invention provides a method for inhibiting biofilm formation on an area of the body (e.g., the skin of a mammal such as a human), the surface of a food, a medical device, a table, floor, or an area that comes into contact with a food or a medical device, comprising contacting the area of the body (e.g., the skin of a mammal such as a human), the surface of a food, the medical device, the table, floor, or the area that comes into contact with a food or a medical device with a polymer or a composition of the invention.

In one embodiment, the invention provides a method for inhibiting biofilm on food storage or food processing equipment comprising contacting the food storage or food processing equipment with a polymer or a composition of the invention.

In one embodiment, the invention provides a method for inhibiting biofilm formation on a personal care product, oral care product, feminine hygiene product, or a wound care product, comprising contacting the personal care product, oral care product, feminine hygiene product, or the wound care product with a polymer or a composition of the invention.

In one embodiment, the invention provides polymers and compositions as described herein for use in medical treatment or diagnosis.

In one embodiment, the invention provides the use of a polymer or composition described herein to prepare a medicament useful for treating a microbial infection in a mammal.

In one embodiment, the invention provides the use of a polymer or composition described herein to prepare, coat or impregnate a medical device.

In one embodiment, the invention provides a pharmaceutical composition comprising a polymer of the invention, and a pharmaceutically acceptable carrier.

In one embodiment, the invention provides a composition comprising a polymer as described herein and an acceptable carrier.

The invention also provides processes and intermediates disclosed herein that are useful for preparing polymers and compositions of the invention.

Detailed Description

The invention provides anhydride polymers having bioactive molecules as a side chain of a polymer. The polymers of the invention have repeating units that comprise residues of two or more bioactive molecules. Accordingly, the polymers of the invention have a high drug loading capacity, which is beneficial.

Bioactive Molecules

Bioactive molecules, also known as bioactives or biologically active molecules, include naturally occurring compounds that are derived from a variety of sources including but not limited to plants, sea creatures, fungi, animals and other microorganisms. Bioactive molecules possess some inherent desirable biological activity, for example, activity directed to macromolecules, cells, tissues, microorganisms, viruses, invertebrates, bacteria, animals, mammals or humans. Sources of bioactive molecules include, for example, essential oils, food, food extracts, plant extracts, natural antimicrobials, nutrachemicals, preservatives, nutraceuticals, phytochemicals and food additives.

In one embodiment of the invention, at least one of the biologically active molecules is an antimicrobial molecule. In one embodiment of the invention, at least one of the biologically active molecules is an antiseptic molecule. In one embodiment of the invention, at least one of the biologically active molecules is an antibiotic molecule.

In one embodiment of the invention, at least one of the biologically active molecules can be obtained from a food. In one embodiment of the invention, at least one of the biologically active molecules can be obtained from a plant. In one embodiment of the invention, at least one of the biologically active molecules can be obtained from an essential oil.

In one embodiment of the invention, at least one of the biologically active molecules is thymol, carvacrol, o-cresol, phenol, guaiacol, eugenol or capsaicin. In one embodiment of the invention, at least one of the biologically active molecules is thymol, carvacrol, eugenol or capsaicin. In one embodiment of the invention, at least one of the biologically active molecules is carvacrol, eugenol, thymol, mescaline, withaferin A, capsaicin, lawsone, lupulone or ß-resercyclic acid. In one embodiment of the invention, at least one of the biologically active molecules is carvacrol, eugenol, thymol, mescaline, withaferin A, capsaicin, lawsone, lupulone or ß-resercyclic acid, austalol, geraniol, linalool, thujanol, myrcenol, terpineol, menthol, piperitol, borneol or citronellol. In one embodiment of the invention, at least one of the biologically active molecules is thiosalicylic acid, 2-mercaptoethanol, erythro- and threo-3-mercapto-2-methylbutanol, (±)2-mercapto-2-methylpentan-1-ol, 3-mercapto-2-methylpentan-1-ol, 3-mercapto-2-methylpentanal, 4-mercapto-4-methyl-2-pentanone, (±)ethyl 3-mercaptobutyrate, 2-methylfuran-3-thiol, 2-furylmethanethiol, trans-p-menthane-8-thiol-3-one, furfuryl mercaptan, 1-*p*-menthene-8-thiol, 8-mercapto-*p*-menthan-3-one, 3-mercaptopropionic acid or 11-mercaptoundecanoic acid.

In one embodiment of the invention, the polymers incorporate thymol, carvacrol, o-cresol, phenol or guaiacol. In one embodiment of the

invention, the, polymers incorporate other food-based bioactives such as eugenol and capsaicin.

In one embodiment the invention provides polyanhydrides with food or nutrachemicals chemically attached as pendant groups.

Polymers of the Invention

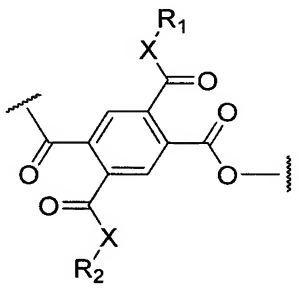
The invention provides a polymer comprising repeating units that form a biodegradable backbone wherein one or more repeating unit comprises at least two pendant residues of a biologically active molecule. In one embodiment, the polymer is a polyanhydride. In another embodiment, the polymer is a polyester, polyamide, or a polycarbonate.

In one embodiment of the invention, the polymer can comprise 2, 5, 10, 25, 50, 75, 0r 100 repeating units. Typically the polymers of the invention have molecular weights of up to about 50,000 amu.

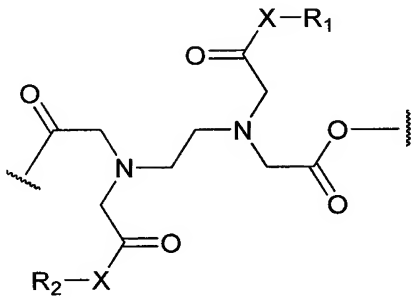
As used herein, a "polyanhydride" is a polymer that has anhydride bonds in the backbone of the polymer. In one embodiment the polyanhydride is formed from monomer units that react to provide the anhydride bonds.

Bioactive molecules are typically incorporated into the polymers of the invention as pendant groups that are not part of the backbone of the polymer. As such, a tracing of the chain of atoms that form the backbone of the polymer would not include the atoms of the residues of the bioactive molecules. In certain embodiments of the invention, the pendant groups can be considered to be sidechains of the polymer. Bioactive molecules can be attached to the remainder of the polymer of the invention through labile (e.g. anhydride, ester, amide or thioester linkages) bonds, that allow for release of the bioloactive molecules upon degradation (e.g. hydrolysis).

In one embodiment, the invention provides a polymer comprising 1 or more units of formula **I, II, III, IV, V** or **VI**:



I



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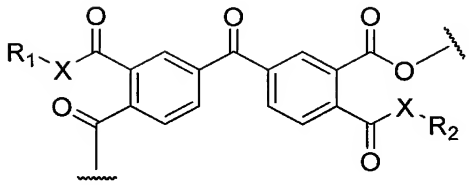
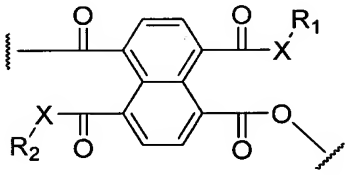


III



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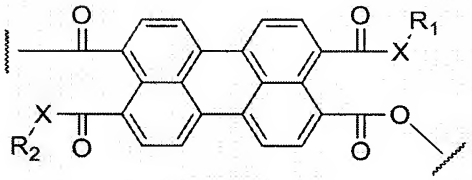
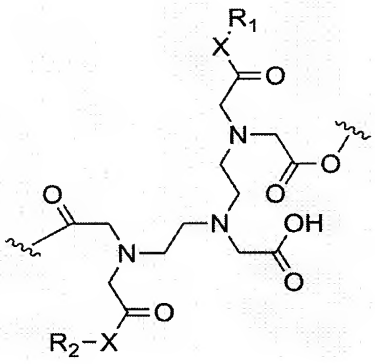


V



VI

wherein;

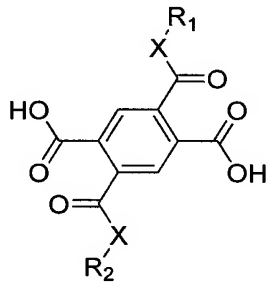
R_1-X- and R_2-X- are each independently a residue of a biologically active molecule;

X is O, S or NR_a; and

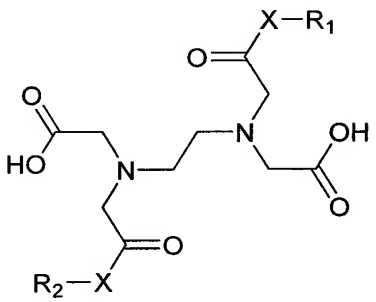
R_a is hydrogen, $(C_1\text{-}C_6)$alkyl or $(C_3\text{-}C_6)$cycloalkyl.

In one embodiment of the invention the polymer comprises at least 2 units of formula **I II, III, IV, V** or **VI.** In one embodiment of the invention the polymer comprises at least 5 units of formula **I, II, III, IV, V** or **VI.** In one embodiment of the invention the polymer comprises at least 10 units of formula **I, II, III, IV, V** or **VI.** In one embodiment of the invention the polymer comprises at least 25 units of formula **I, II, III, IV, V** or **VI.** In one embodiment of the invention the polymer comprises at least 50 units of formula **I, II, III, IV, V** or **VI.** In one embodiment of the invention the polymer comprises at least 75 units of formula **I, II, III, IV, V** or **VI.** In one embodiment of the invention the polymer comprises at least 100 units of formula **I, II, III, IV, V** or **VI.** In one embodiment of the invention, the units of formula **I, II, III, IV, V or VI** are repeating units.

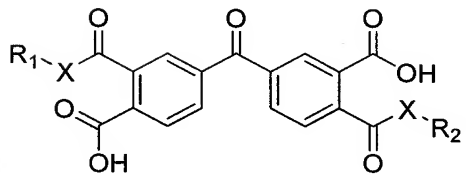
In another embodiment, the invention provides an intermediate of formula **Ib, IIb, IIIb, IVb, Vb or VIb**:



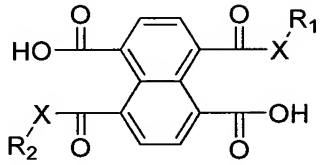
Ib



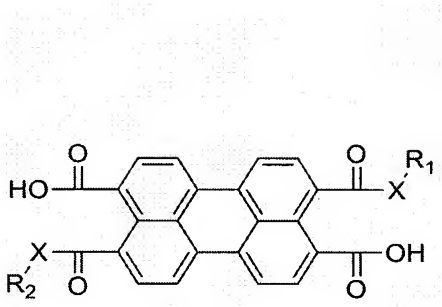
IIb



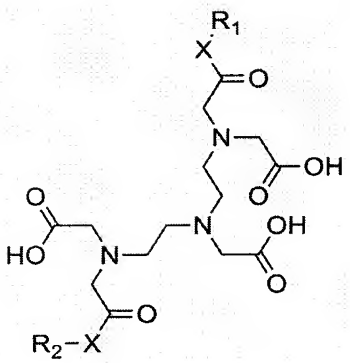
IIIb



IVb



Vb



VIb

or a salt thereof, wherein:

R_1-X- and R_2-X- are each independently a residue of a biologically active molecule;

X is O, S or NR_a; and

R_a is hydrogen, $(C_1\text{-}C_6)$alkyl or $(C_3\text{-}C_6)$cycloalkyl,

that is useful for preparing the polymers of the invention.

In one embodiment of the invention the polymer comprises at least two different biologically active residues, i.e. R_1-X- and R_2-X- differ.

Combinations

Additional bioactive agents can be incorporated into the polymer backbone, included as pendant groups, or dispersed in the matrix of the polymers of the invention. Accordingly, the invention also comprises compositions comprising such combinations.

In one embodiment the invention provides a composition further comprising salicylic acid or salicylsalicylic acid. In one embodiment the invention provides a composition further comprising an antibiotic. In one embodiment the invention provides a composition further comprising at least one of triclosan, propylparaben, nisin, and polylysine. In one embodiment the invention provides a composition further comprising at least one of triclosan, propylparaben, nisin, polylysine ε-polysine, nanomyicin, sorbic acid, wintergreen, polyarginine, chitosan, α-tocoperol, alliin, allicin, ferulic

acid, lutein, cichoric acid, cinnamic aldehyde, neral, geranial, citronellal, cuminal, verbenone, thujone, borneone, pinocamphone, cryptone, carvone, fenchone, piperitone, menthone, estragole, anethole, phtalids, cineole or phellandral.

Preparation of Polymers of the Invention

Polymers of the invention with the bioactives attached as a pendant group can be prepared using standard polymer techniques that are well known in the art for preparing such polymers, e.g. polyesters, polyamides, polycarbonates, and polyanhydrides. For example, representative polymers of the invention can be prepared by melt-condensation polymerization or by solution polymerization techniques starting with appropriate monomers (see *Chem. Rev*, **1999**, *99*, 3181-3198).

Synthetic procedures for incorporating bioactive molecules with one reactive functional group into polymers have been established and are described herein. In these methods, the bioactive molecule may be attached prior to polymerization, so the number of bioactive molecules attached is well defined. These polymers should typically degrade and release the incorporated bioactive molecules, e.g. to prevent the formation of biofilms. These biodegradable polymers can be formulated into food products and various active food packaging materials. In addition, these polymers may be effective for control of biofilms and bacterial growth in medical devices, oral care and personal care products.

As described herein, di-anhydrides can be ring-opened to generate ester bonds with the bioactive molecules. In some embodiments, symmetrical di-anhydrides are used, which simplifies the chemical characterization, and likely the degradation products of the polymer. Asymmetrical di-anhydrides can also be utilized. In one embodiment of the invention, pyromellitic acid can be incorporated into the polymer of the invention. In one embodiment of the invention ethylenediaminetetraacetic acid can be incorporated into the polymer of the invention. In one embodiment of the invention 3,3',4,4'-benzophenone tetracarboxylic acid

can be incorporated into the polymer of the invention. In one embodiment of the invention 1,4,5,8-naphthalene tetracarboxylic acid can be incorporated into the polymer of the invention. In one embodiment of the invention 3,4,9,10-perylenetetracarboxylic acid can be incorporated into the polymer of the invention. In one embodiment of the invention diethylenetriaminepentaacetic dianhydride can be incorporated into the polymer of the invention.

In one embodiment of the invention, aromatic monomers may be used, for easy identification during polymer degradation studies.

The invention also provides methods for preparing polymers of the invention and methods for preparing intermediate diacid monomers that are useful for preparing polymers of the invention. For example, in one embodiment, the invention provides a method for preparing a diacid monomer comprising reacting a bioactive molecule with a symmetrical cyclic pyromellitic dianhydride to provide the diacid with the bioactives attached through ester linkages. In one embodiment, the invention provides a method for preparing a diacid monomer comprising reacting a bioactive molecule with ethylenediaminetetraacetic acid dianhydride to form the diacid, with the bioactives attached through ester linkages. In one embodiment, the invention provides a method for preparing a diacid monomer comprising reacting a bioactive molecule with 3,3',4,4' – benzophenone tetracarboxylic dianhydride to form the diacid, with the bioactives attached through ester linkages. In one embodiment, the invention provides a method for preparing a diacid monomer comprising reacting a bioactive molecule with 1,4,5,8-naphthalene tetracarboxylic dianhydride to form the diacid with the bioactives attached through ester linkages. In one embodiment, the invention provides a method for preparing a diacid monomer comprising reacting a bioactive molecule with 3,4,9,10-perylene tetracarboxylic dianhydride to form the diacid with the bioactives attached through ester linkages. In one embodiment, the invention provides a method for preparing a diacid monomer comprising reacting a bioactive molecule with

diethylenetriaminepentaacetic dianhydride to form the diacid, with the bioactives attached through ester linkages.

In one embodiment, the invention provides a method for preparing a diacid monomer comprising reacting a bioactive molecule with a symmetrical cyclic pyromellitic dianhydride to form the diacid, with the bioactives attached through amide linkages. In one embodiment, the invention provides a method for preparing a diacid monomer comprising reacting a bioactive molecule with ethylenediaminetetraacetic acid dianhydride to form the diacid, with the bioactives attached through amide linkages. In one embodiment, the invention provides a method for preparing a diacid monomer comprising reacting a bioactive molecule with 3,3',4,4' – benzophenone tetracarboxylic dianhydride to form the diacid, with the bioactives attached through amide linkages. In one embodiment, the invention provides a method for preparing a diacid monomer comprising reacting a bioactive molecule with 1,4,5,8-naphthalene tetracarboxylic dianhydride to form the diacid, with the bioactives attached through amide linkages. In one embodiment, the invention provides a method for preparing a diacid monomer comprising reacting a bioactive molecule with 3,4,9,10-perylene tetracarboxylic dianhydride to form the diacid, with the bioactives attached through amide linkages. In one embodiment, the invention provides a method for preparing a diacid monomer comprising reacting a bioactive molecule with diethylenetriaminepentaacetic dianhydride to form the diacid, with the bioactives attached through amide linkages.

In one embodiment, the invention provides a method for preparing a diacid monomer comprising reacting a bioactive molecule with symmetrical cyclic pyromellitic dianhydride to form the diacid, with the bioactives attached through thioester linkages. In one embodiment, the invention provides a method for preparing a diacid monomer comprising reacting a bioactive molecule with ethylenediaminetetraacetic acid dianhydride to form the diacid, with the bioactives attached through thioester linkages. In one embodiment, the invention provides a method for preparing a diacid monomer comprising reacting a bioactive molecule with 3,3',4,4' –

benzophenone tetracarboxylic dianhydride to form the diacid, with the bioactives attached through thioester linkages. In one embodiment, the invention provides a method for preparing a diacid monomer comprising reacting a bioactive molecule with 1,4,5,8-naphthalene tetracarboxylic dianhydride to form the diacid, with the bioactives attached through thioester linkages. In one embodiment, the invention provides a method for preparing a diacid monomer comprising reacting a bioactive molecule with 3,4,9,10-perylene tetracarboxylic dianhydride to form the diacid, with the bioactives attached through thioester linkages. In one embodiment, the invention provides a method for preparing a diacid monomer comprising reacting a bioactive molecule with diethylenetriaminepentaacetic dianhydride to form the diacid, with the bioactives attached through thioester linkages.

Specific Values

Specific values listed below for radicals, substituents, and ranges, are for illustration only; they do not exclude other values or other values within defined ranges for the radicals and substituents, Specifically, (C_1-C_6)alkyl can be methyl, ethyl, propyl, isopropyl, butyl, iso-butyl, sec-butyl, pentyl, 3-pentyl, or hexyl and (C_3-C_6)cycloalkyl can be cyclopropyl, cyclobutyl, cyclopentyl, or cyclohexyl.

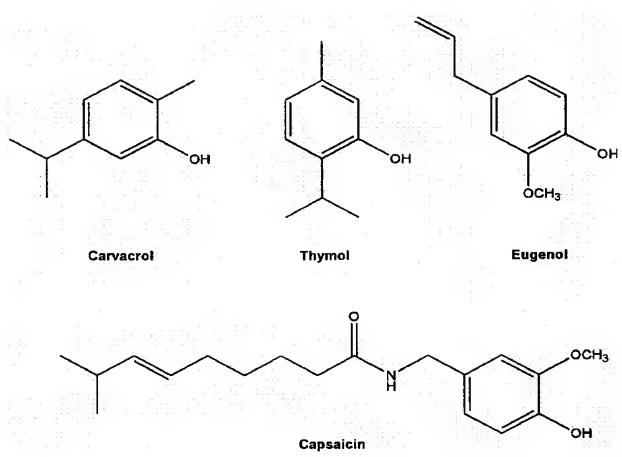
It will be appreciated by those skilled in the art that compounds of the invention having a chiral center may exist in and be isolated in optically active and racemic forms. Some compounds may exhibit polymorphism. It is to be understood that the present invention encompasses any racemic, optically-active, polymorphic, regioisomeric or stereoisomeric form, or mixtures thereof, of a compound of the invention, which possess the useful properties described herein, it being well known in the art how to prepare optically active forms (for example, by resolution of the racemic form by recrystallization techniques, by synthesis from optically-active starting materials, by chiral synthesis, or by chromatographic separation using a chiral stationary phase).

This invention provides polymers that allow an expanded number of bioactive molecules to be chemically incorporated into the polymer structure. Such polymers have applications in a broad range of fields including medical and food-related applications. The polymers can release the bioactive chemically incorporated into the sidechain of the polymer as well as an additional bioactive, e.g., if previously admixed. In some embodiments, the polymers and compositions comprising the polymers are active against *P. aeruginosa*, *E. coli*, *Listeria monocytogenes*, or *Salmonella*. In some embodiments, the polymers and compositions comprising the polymers can be applied on medical devices, food, or areas that come into contact with medical devices or food.

Certain embodiments of the invention will now be illustrated by the following non-limiting Example.

Example 1: Preparation of Representative Polymers of the Invention

Polyanhydrides prepared from antimicrobials derived from natural sources such as spices and plant extracts were designed and synthesized (**Schemes 1 and 2**) (Cowan, M.M. Clinical Microbiology Reviews 1999 12, 564-582) One application of these polymers is their formulation into micro- or nanospheres, which can then be mixed with foods. The polymers could also be used to coat food processing equipment. Alternatively, other bioactive agents can be physically admixed into the antimicrobial-based polyanhydrides to result in a dual action delivery device.



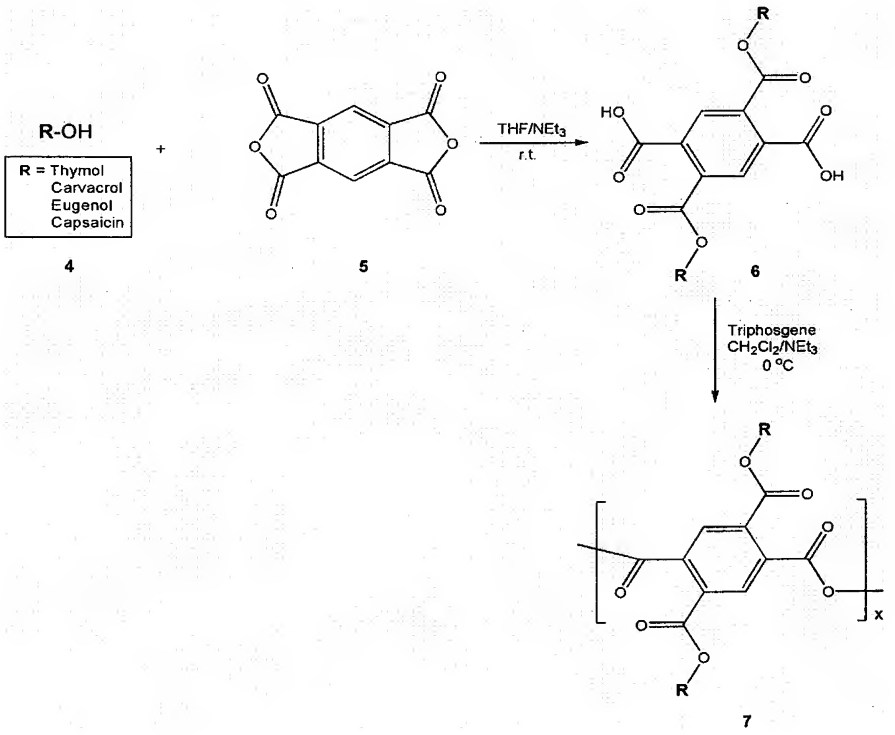
Scheme 1: Natural antimicrobial agents incorporated into polyanhydrides.

Experimental

Instrumentation. Polymers and intermediates were characterized by proton nuclear magnetic resonance (^{1}H NMR) and Fourier transform infrared spectroscopy (FTIR). Polymer properties were determined using gel permeation chromatography (GPC) for molecular weights and polydispersity, thermogravimetric analysis (TGA) for decomposition temperatures (T_d), and differential scanning calorimetry (DSC) for glass transition (T_g) and melting (T_m) temperatures.

Synthesis of Polyanhydrides. Polyanhydrides were synthesized using solution polymerization (**Scheme 2**) (Domb, A.; Ron, E.; Langer, R. Macromolecules 1988, 21, 1925). In brief, the diacid (**6**) was prepared by a ring-opening of pyromellitic anhydride (**5;** 7.5 mmol) with the mono-functional antimicrobial compound (**4**; 15 mmol) in the presence of a base (e.g., triethylamine; 53 mmol) and in an appropriate solvent (e.g., THF; 40 mL). After the reaction was stirred for 2 h under nitrogen, it was poured over water (~ 400 mL) and acidified using concentrated HCl. The solid formed (**6**) was vacuum filtered, washed with water (3 x 100 mL) and dried under vacuum at room temperature. Diacid (**6**) (4.6 mmol) was dissolved 20 % (w/v) CH_2Cl_2 and triethylamine (20 mmol). The reaction was cooled to 0 °C. The coupling reagent, triphosgene (5.1 mmol), dissolved in CH_2Cl_2 (5 mL)

was added drop-wise to the reaction mixture. The reaction was allowed to stir for 2 h at 0 °C under nitrogen. It was then poured over diethyl ether (~ 100 mL), and the polymer formed (**7**) was vacuum filtered, washed with acidified water (3 x 100 mL; pH 2 using concentrated HCl) and dried under vacuum at room temperature.



Scheme 2: Synthetic scheme for the chemical incorporation of a mono-functional antimicrobial (**4**) into the polyanhydride (**7**).

Polymers comprising bioactive molecules linked to the polymer by thioester bonds can be prepared by following the reaction sequence outlined in Scheme 3. For these polymers the ROH (4) starting material is replaced with bioactive molecules of formula RSH. Polymers comprising bioactive molecules linked to the polymer by amide bonds can be prepared by following the reaction sequence outlined in Scheme 3 as well. For these polymers the ROH (4) starting material is replaced with bioactive molecules of formula $RNHR_a$ wherein R_a is hydrogen, $(C_1\text{-}C_6)$alkyl or $(C_3\text{-}C_6)$cycloalkyl.

Antimicrobial-based polyanhydrides have been successfully synthesized by incorporating the bioactive agent into the polymer backbone *via* an ester linkage. The polymer drug loadings were 58-60 % by weight with nearly uniform polymer chain lengths and a T_g near body temperature (*see* Table 1).

Due to the instability of the anhydride and ester bonds, these polymers should degrade to release the active antimicrobial compounds.

Table 1

Bioactive	M_w	PDI	T_d (°C)	T_g (°C)
Thymol	38,000	1.0	179	37
Carvacrol	21,700	1.0	182	27
Eugenol	19,900	1.0	171	58

Biofilm Assays on Polymer Surfaces

S. typhimurium MAE52 was used to study inhibition of biofilm formation on polymer-coated glass coverslips. The results are depicted in Table 2.

Table 2. Pyromellitic Acid Polymers

Bioactive	Observations
Thymol	Prevented cell growth almost completely.
Carvacrol	Formed weak biofilms after 24 h.
Eugenol	Formed full biofilms after 24 h.

Polymers based on plant and spice extracts are unique as their components are not synthetic, but natural, antimicrobials. This may be desirable if the polyanhydrides are to be mixed with foods, used in food processing and/or packaging materials.

Conclusions

Biodegradable polyanhydrides with natural antimicrobial properties were synthesized and characterized to be used to inhibit/prevent biofilm formation. Since the polymers can degrade to release the bioactives, they will be very useful in controlled delivery applications for the food industry and other such areas.

Example 2: Preparation of Representative Polymers of the Invention

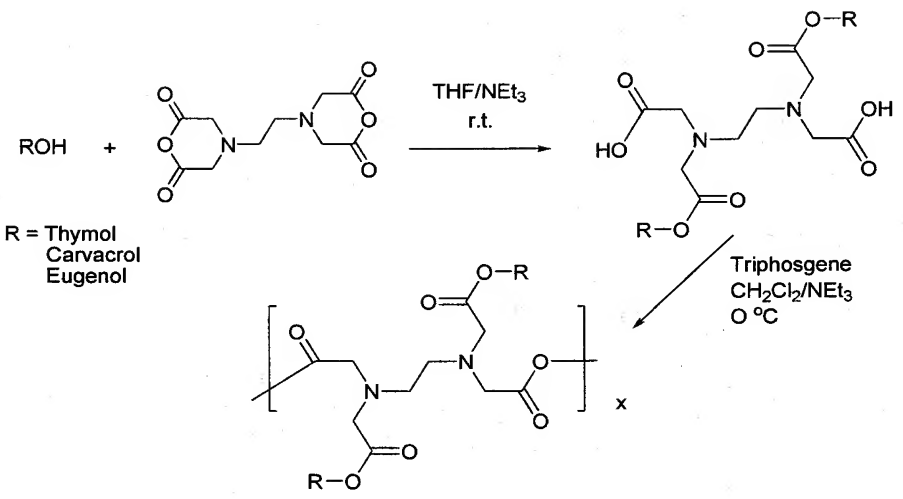
Polyanhydrides were designed and prepared from antimicrobials derived from natural sources such as spices and plant extracts. Incorporation of these bioactive molecules into the polymers results in biodegradable polyanhydrides that slowly release the bioactive agents to reduce or prevent biofilm formation, *e.g.*, when incorporated into food and food packaging materials.

Plant-based Polymers: Choice of Bioactive Molecules

Plant and plant extract-based polymers were designed using the natural antimicrobials carvacrol, eugenol, and thymol. Polymers were derived from these bioactive molecules to prevent biofilm formation, *e.g.*, when formulated into food products, food packaging materials and food processing equipment.

Ethylenediaminetetraacetic Acid (EDTA) Polymers

The biocompatible food-grade chelating EDTA was used as a polymer precursor. EDTA is widely used as preservative in packaged foods, vitamins, and personal care products. As depicted below, ring-opening with symmetrical EDTA dianhydride to form diacids with the bioactives attached as ester linkages was performed via procedures similar to those of Example 1.



Scheme 3: Synthetic scheme for the chemical incorporation of an antimicrobial into a representative polymer of the invention.

Antimicrobial-based polyanhydrides were successfully synthesized. The polymer drug loadings were 54-56 % by weight with nearly uniform polymer chain lengths and a T_g well above body temperature (*see* Table 3).

Table 3

Bioactive	M_w	PDI	T_d (°C)	T_g (°C)
Thymol	23,200	1.0	223	77
Carvacrol	19,500	1.1	221	65
Eugenol	11,100	1.5	229	86

Biofilm Assays on Polymer Surfaces

S. typhimurium MAE52 was used to study inhibition of biofilm formation on polymer-coated glass coverslips. The results are depicted in Table 4.

Table 4. EDTA Linker

Bioactive	Observations
Thymol	Formed weak biofilms after 24 h.
Carvacrol	Completely prevented biofilm formation.
Eugenol	Formed cell aggregates after 32 h.

The hydrolytic degradation of representative polymers of the invention can be evaluated as described in Example 3.

Example 3: Hydrolytic degradation of representative polymers

Hydrolytic degradation of representative polymers can be studied to determine the rate of release of the natural antimicrobial from the polymer backbone. Polymers will be incubated in PBS (pH 7.4) at 37 °C. At predetermined time intervals, the media will be replaced with fresh media, and the spent media will be analyzed by HPLC. See for example: Whitaker-Brothers, K.; Uhrich, K. E. *J. Biomed. Mater. Res.* **2006**, *76A*, 470-479; Prudencio, A.; Schmeltzer, R. C.; Uhrich, K. E. *Biomacromolecules* **2005**, *38*, 6895-6901; and Bryers, J. D.; Jarvis, R. A.; Lebo, J.; Prudencio, A.; Kyriakides, T. R.; Uhrich, K. *Biomaterials* **2006**, *27*, 5039-5048.

All publications, patents and patent applications cited herein are incorporated herein by reference. While in the foregoing specification this invention has been described in relation to certain embodiments thereof, and many details have been set forth for purposes of illustration, it will be apparent to those skilled in the art that the invention is susceptible to additional embodiments and that certain of the details described herein may be varied considerably without departing from the basic principles of the invention.

Claims

What is claimed is:

1. A polymer comprising repeating units that form a biodegradable backbone wherein one or more repeating unit comprises at least two pendant residues of a biologically active molecule.

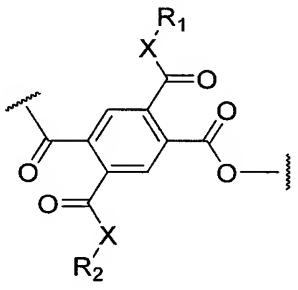
2. The polymer of claim 1 wherein each repeating unit comprises at least two pendant residues of a biologically active molecule.

3. The polymer of claim 1 that comprises at least 10 repeating units.

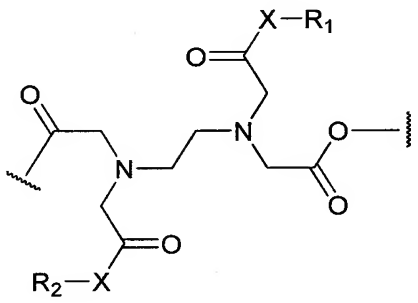
4. The polymer of claim 1 that comprises at least 50 repeating units.

5. The polymer of claim 1 which is a polyanhydride.

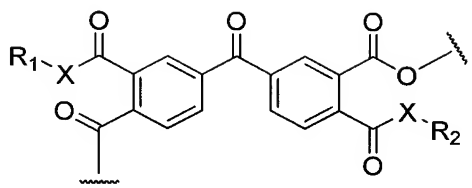
6. The polyanhydride of claim 5 that comprises 1 or more units of formula **I, II, III, IV,V or VI**:



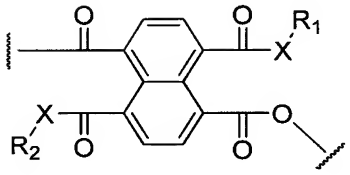
I



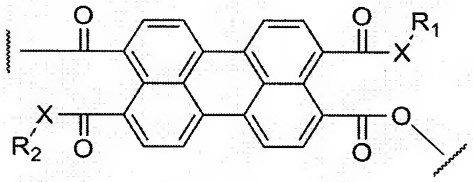
II



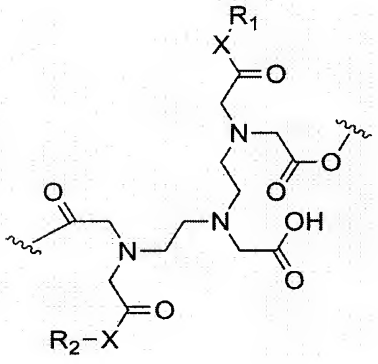
III



IV



V



VI

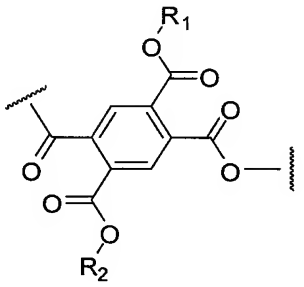
wherein;

R_1-X- and R_2-X- are each independently a residue of a biologically active molecule;

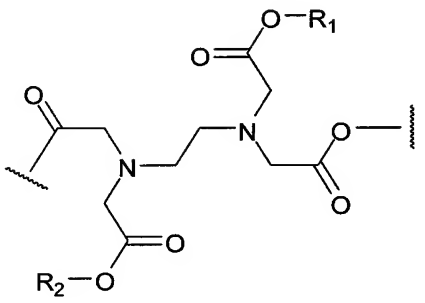
X is O, S or NR_a; and

R_a is hydrogen, $(C_1\text{-}C_6)$alkyl or $(C_3\text{-}C_6)$cycloalkyl.

7. The polyanhydride of claim 5 that comprises or more units of formula **Ia** or **IIa**:



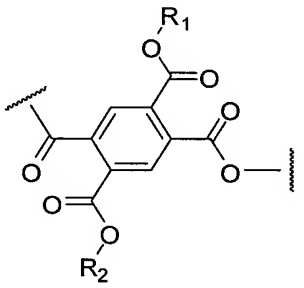
Ia



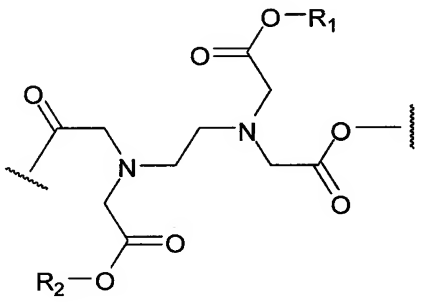
IIa

wherein R_1-O- and R_2-O- are each independently a residue of a biologically active molecule.

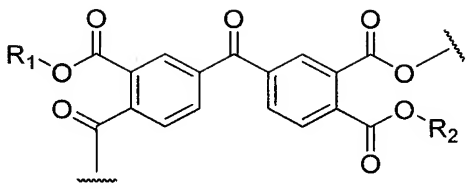
8. The polyanhydride of claim 5 that comprises or more units of formula **Ia, IIa, IIIa, IVa, Va or VIa**:



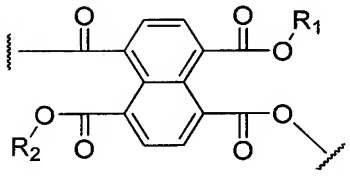
Ia



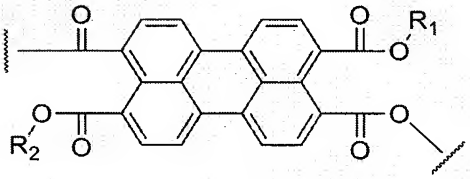
IIa



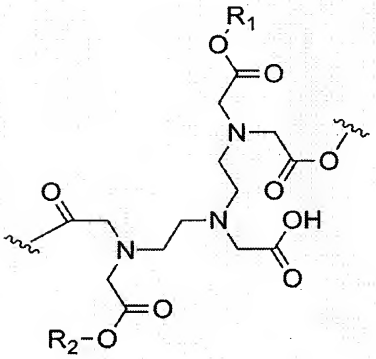
IIIa



IVa



Va



VIa

wherein R_1-O- and R_2-O- are each independently a residue of a biologically active molecule.

9. The polymer of any one of claims 1-8, wherein at least one of the biologically active molecules is an antimicrobial molecule.

10. The polymer of any one of claims 1-8, wherein at least one of the biologically active molecules is an antiseptic molecule.

11. The polymer of any one of claims 1-8, wherein at least one of the biologically active molecules is an antibiotic molecule.

12. The polymer of any one of claims 1-8, wherein at least one of the biologically active molecules can be obtained from a plant.

13. The polymer of any one of claims 1-8, wherein at least one of the biologically active molecules can be obtained from an essential oil.

14. The polymer of any one of claims 1-8, wherein at least one of the biologically active molecules is thymol, carvacrol, o-cresol, phenol, guaiacol, eugenol or capsaicin.

15. The polymer of any one of claims 1-8, wherein at least one of the biologically active molecules is thymol, carvacrol, eugenol or capsaicin.

16. The polymer of any one of claims 1-8, wherein at least one of the biologically active molecules is carvacrol, eugenol, thymol, mescaline, withaferin A, capsaicin, lawsone, lupulone or ß-resercyclic acid, austalol, geraniol, linalool, thujanol, myrcenol, terpineol, menthol, piperitol, borneol or citronellol.

17. The polymer of any one of claims 1-8, wherein at least one of the biologically active molecules is carvacrol, eugenol, thymol, mescaline, withaferin A, capsaicin, lawsone, lupulone or ß-resercyclic acid.

18. The polymer of any one of the claims 1-8 wherein at least one of the biologically active molecules is thiosalicylic acid, 2-mercaptoethanol, erythro- and threo-3-mercapto-2-methylbutanol, (±)2-mercapto-2-methylpentan-1-ol, 3-mercapto-2-methylpentan-1-ol, 3-mercapto-2-methylpentanal, 4-mercapto-4-methyl-2-pentanone, (±)ethyl 3-mercaptobutyrate, 2-methylfuran-3-thiol, 2-furylmethanethiol, trans-p-menthane-8-thiol-3-one, furfuryl mercaptan, 1-*p*-menthene-8-thiol, 8-mercapto-*p*-menthan-3-one, 3-mercaptopropionic acid or 11-mercaptoundecanoic acid.

19. A pharmaceutical composition comprising a polymer as described in any one of claims 1-18 and a pharmaceutically acceptable carrier.

20. A composition comprising a polymer as described in any one of claims 1-18 and an acceptable carrier.

21. The composition of claim 19 or 20, further comprising salicylic acid.

22. The composition of claim 19 or 20, further comprising salicylsalicylic acid.

23. The composition of any one of claims 19-22, further comprising an antibiotic.

24. The composition of any one of claims 19-23, further comprising at least one of triclosan, propylparaben, nisin, polylysine ε-polysine, nanomyicin, sorbic acid, wintergreen, polyarginine, chitosan, α-tocoperol, alliin, allicin, ferulic acid, lutein, cichoric acid, cinnamic aldehyde, neral, geranial, citronellal, cuminal, verbenone, thujone, borneone, pinocamphone, cryptone, carvone, fenchone, piperitone, menthone, estragole, anethole, phtalids, cineole and phellandral.

25. The composition of any one of claims 19-23, further comprising at least one of triclosan, propylparaben, nisin, and polylysine.

26. A food product comprising the polymer or composition of any one of claims 1-25.

27. A confectionery comprising the polymer or composition of any one of claims 1-25.

28. A method for inhibiting biofilm formation on an area, comprising contacting the area with an effective amount of the polymer, composition or food product of any one of claims 1-25.

29. The method of claim 28, wherein the area is an area of a body, the surface of a food, a medical device, table, floor, personal care product, oral care product, feminine hygiene product, wound care product or an area that comes into contact with a food or a medical device.

30. The method of claim 28, wherein the area is an area of a body, the surface of a food, a medical device, table, floor or an area that comes into contact with a food or a medical device.

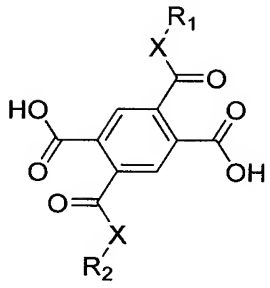
31. A medical device comprising the polymer or composition of any one of claims 1-25.

32. A medical device of claim 30 wherein the polymer or composition is coated onto or impregnated within the device.

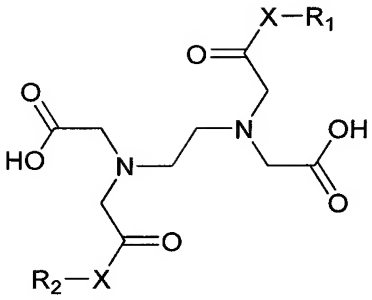
33. A polymer as described by any one of claims 1-18 for use in medical treatment or diagnosis.

34. The use of a polymer as described in any one of claims 1-18 to prepare a medicament useful for treating a microbial infection in a mammal.

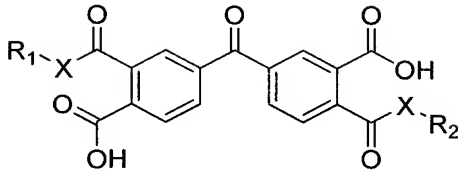
35. A compound of formula **Ib, IIb, IIIb, IVb, Vb or VIb**:



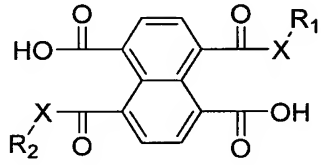
Ib



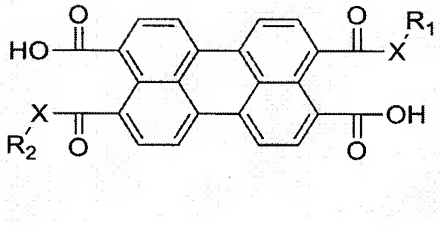
IIb



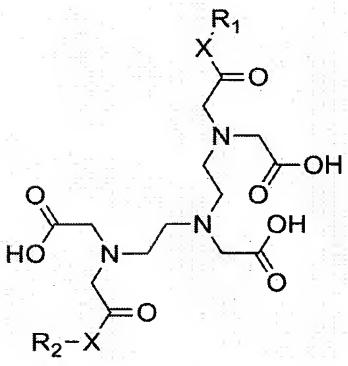
IIIb



IVb



Vb



VIb

or a salt thereof, wherein:

R_1-X- and R_2-X- are each independently a residue of a biologically active molecule;

X is O, S or NR_a; and

R_a is hydrogen, $(C_1\text{-}C_6)$alkyl or $(C_3\text{-}C_6)$cycloalkyl.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 08/60254

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - A61K 31/00; C07H 19/20 (2008.04)
USPC - 424/78.3; 536/26.21
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
USPC: 424/78.3; 536/26.21

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC: 424/$; 536/$; 514/$ (see search terms below)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWest: PGPB,USPT,USOC,EPAB,JPAB Google Patents, Google Scholar, Google
biologically, active, thymol, polyanhydrides, eugenol, plants, carvacrol, capsaicin, R1-O- R2-O-, independently, independent, polymer, repeating units, pendant, biodegradable, formula, alkyl, R1-X-, two pendant, each, repeat, units

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2006/0188546 A1 (Giroux) 24 August, 2006 (24.08.2006), para [0005], [0107]-[0108], [0110], [0114], [0128], [0132], [0160], [0228]	1-18
Y	US 4,115,169 A (Emmons et al.) 19 September, 1978 (19.09.1978), col 1, ln 19; col 2, ln 48-49;col 3, ln 17	1-18
Y	US 2005/0131199 A1 (Uhrich et al.) 16 June, 2005 (16.06.2005), para [0007]- [0008], [0012], [0043], [0048], [0063]	6 and 18
Y	US 2005/0113549 A1 (Devlin et al.) 26 May, 2005 (26.05.2005), para [0108]	7 and 8
Y	US 2005/0260651 A1 (Calias et al.) 24 November, 2005 (24.11.2005), para [0015], [0065]	12
Y	US 2004/0062778 A1 (Shefer et al.) 01 April, 2004 (01.04.2004), para [0017]) [0097]).	13-17

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
06 July, 2008 (06.07.2008)	15 JUL 2008
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (April 2007)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 08/60254

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claims Nos.: 19-34
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.